



US010175117B2

(12) **United States Patent**
Branken et al.

(10) **Patent No.:** **US 10,175,117 B2**
(45) **Date of Patent:** **Jan. 8, 2019**

(54) **TEMPERATURE SENSING ASSEMBLY FOR MEASURING TEMPERATURE OF A WALL OF A HIGH TEMPERATURE VESSEL**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 360 days.

(21) Appl. No.: **14/994,962**

(22) Filed: **Jan. 13, 2016**

(65) **Prior Publication Data**
US 2017/0199085 A1 Jul. 13, 2017

(51) **Int. Cl.**
G01K 1/02 (2006.01)
G01K 1/14 (2006.01)
G01K 7/04 (2006.01)

(52) **U.S. Cl.**
CPC **G01K 1/026** (2013.01); **G01K 1/14** (2013.01); **G01K 7/04** (2013.01)

(58) **Field of Classification Search**
CPC G01K 1/026; G01K 1/14; G01K 7/04
USPC 374/147, 166, 137, 208, 179; 136/230, 136/233
See application file for complete search history.

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(57) **ABSTRACT**

A temperature sensing assembly for measuring the temperature of an inner wall of a high temperature vessel includes a thermocouple assembly having multiple junction points to provide indications of temperature. The assembly further includes support structures for supporting the thermocouple assembly in the interior space of the vessel and to maintain the junction points proximate the inner wall of the vessel.

7 Claims, 9 Drawing Sheets

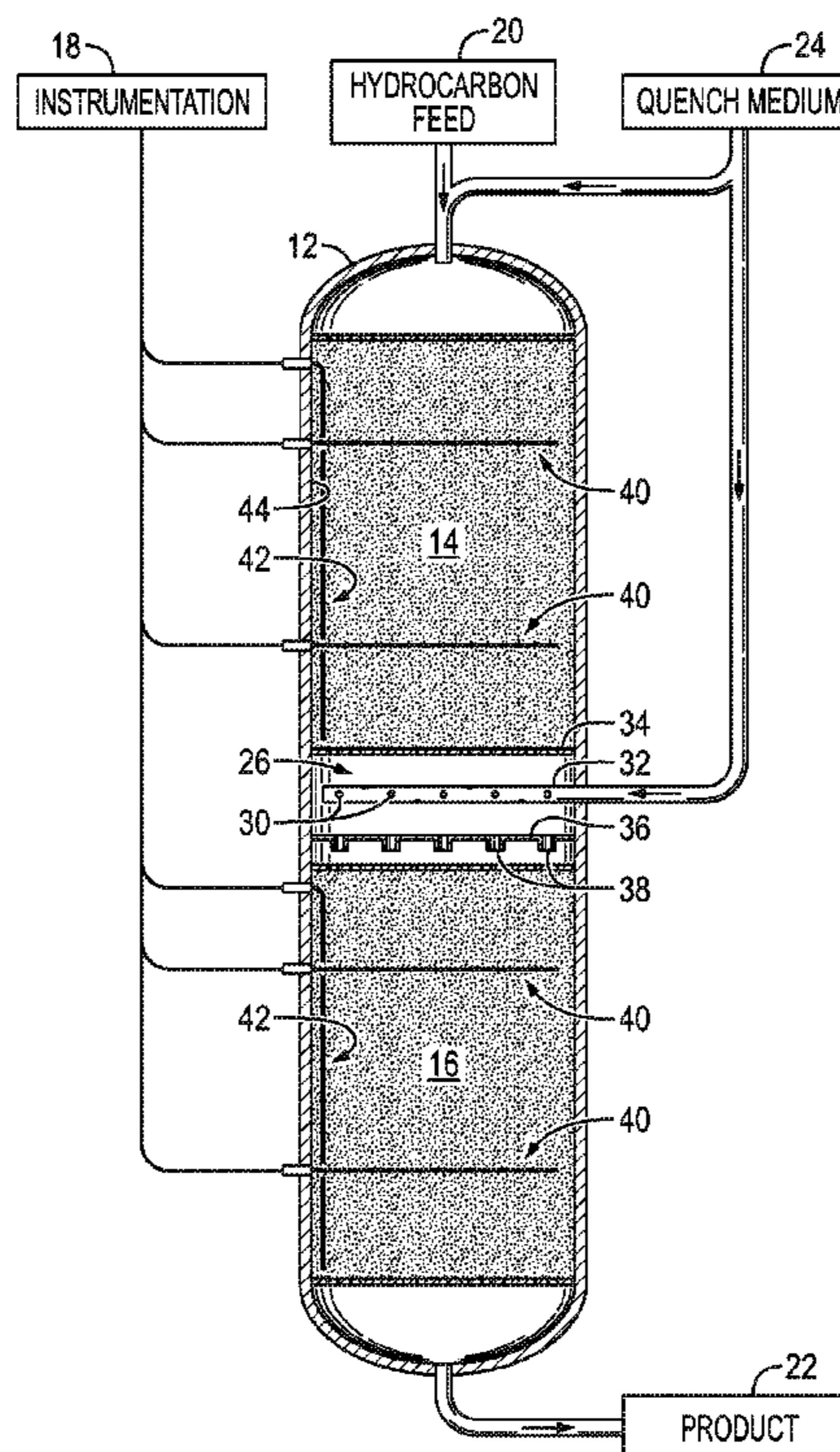


FIG. 1

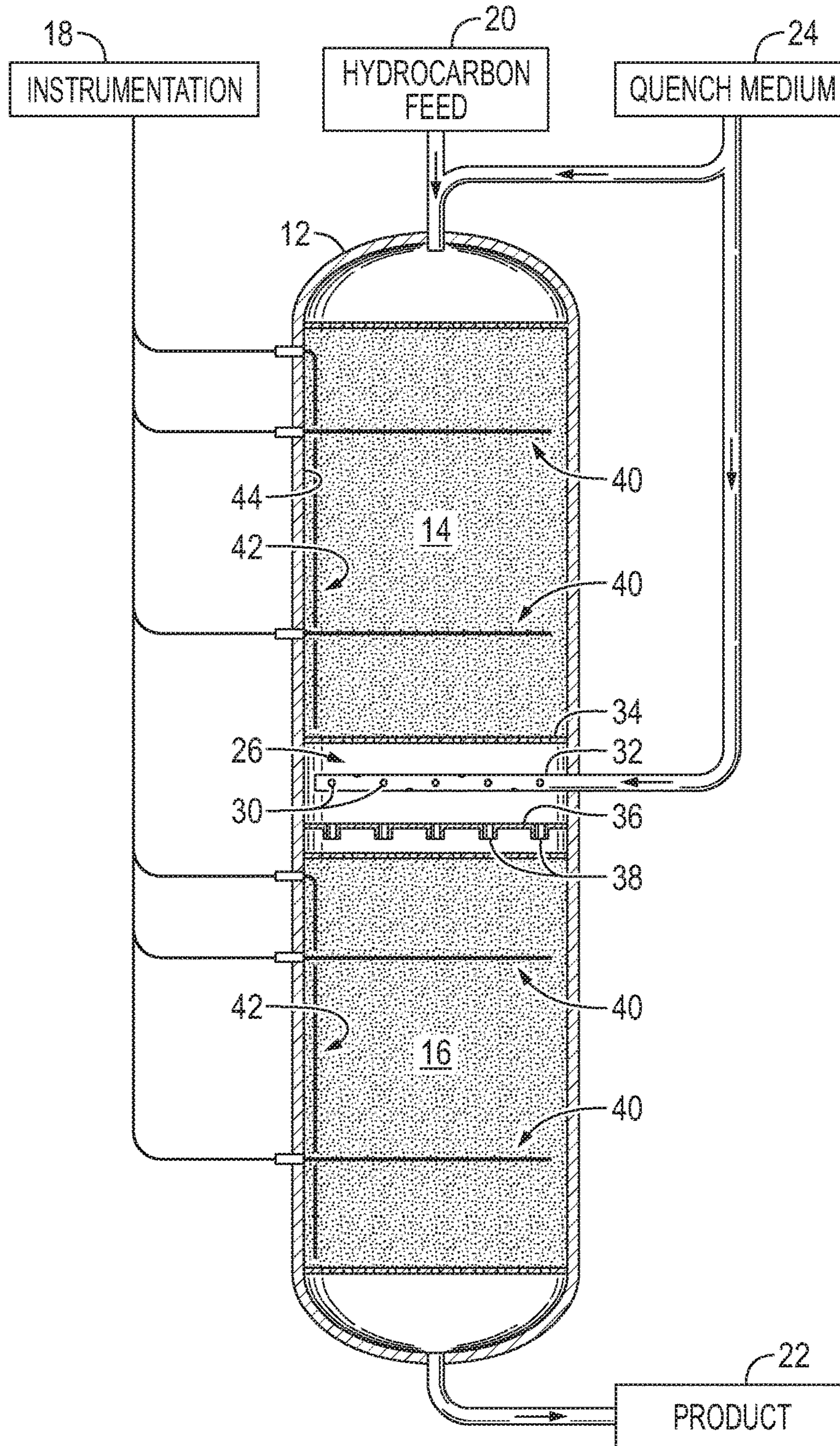


FIG. 2

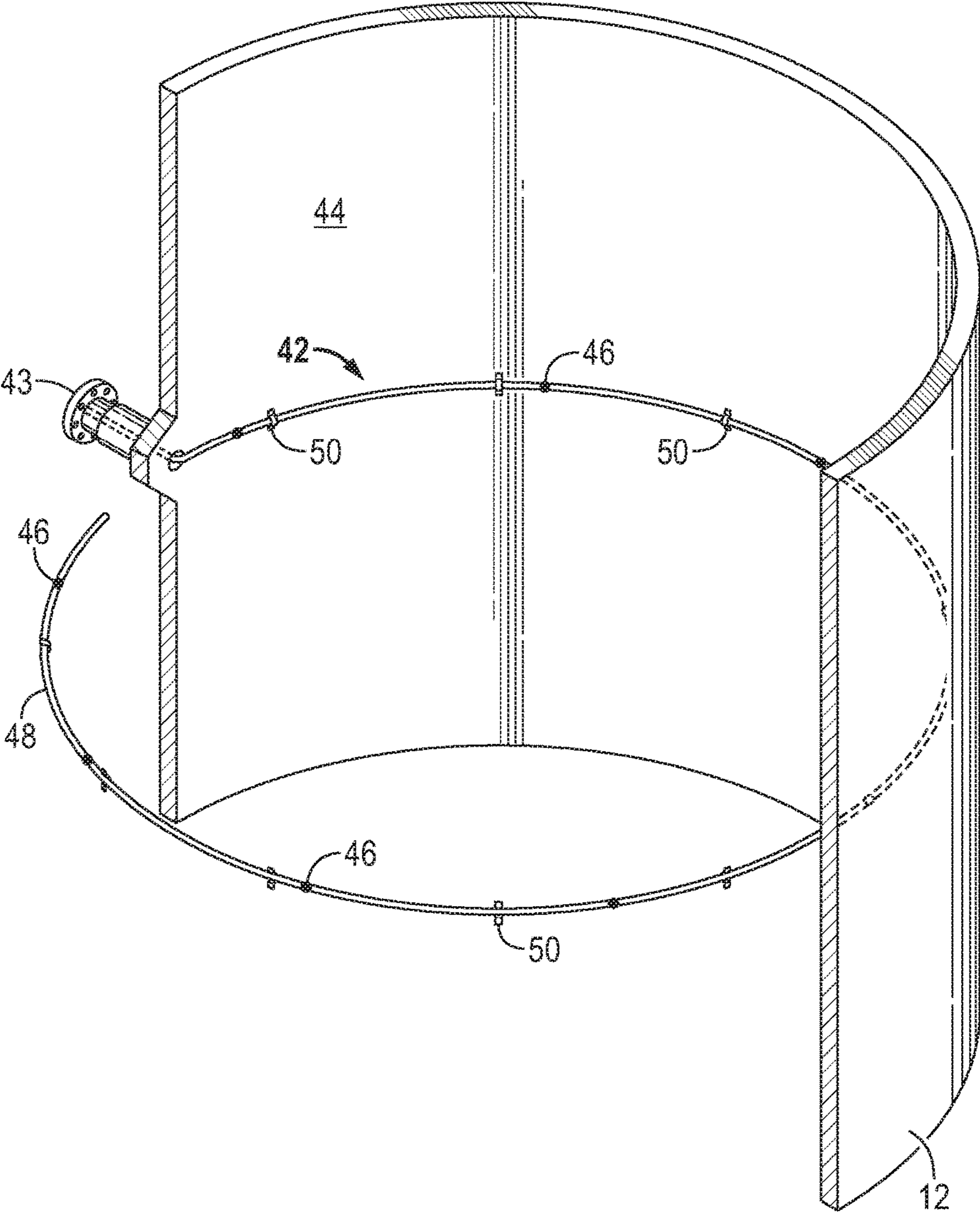


FIG. 3

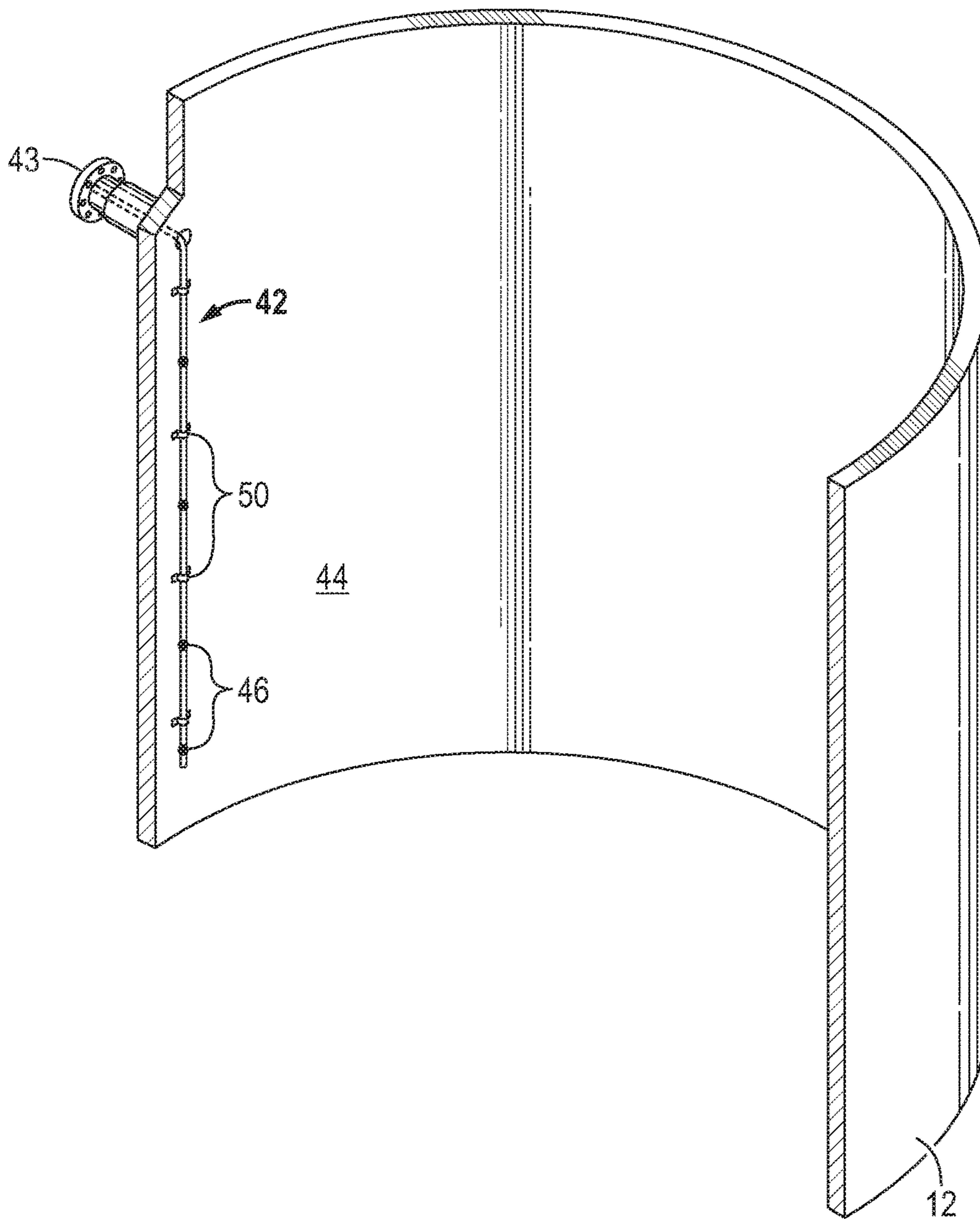


FIG. 4

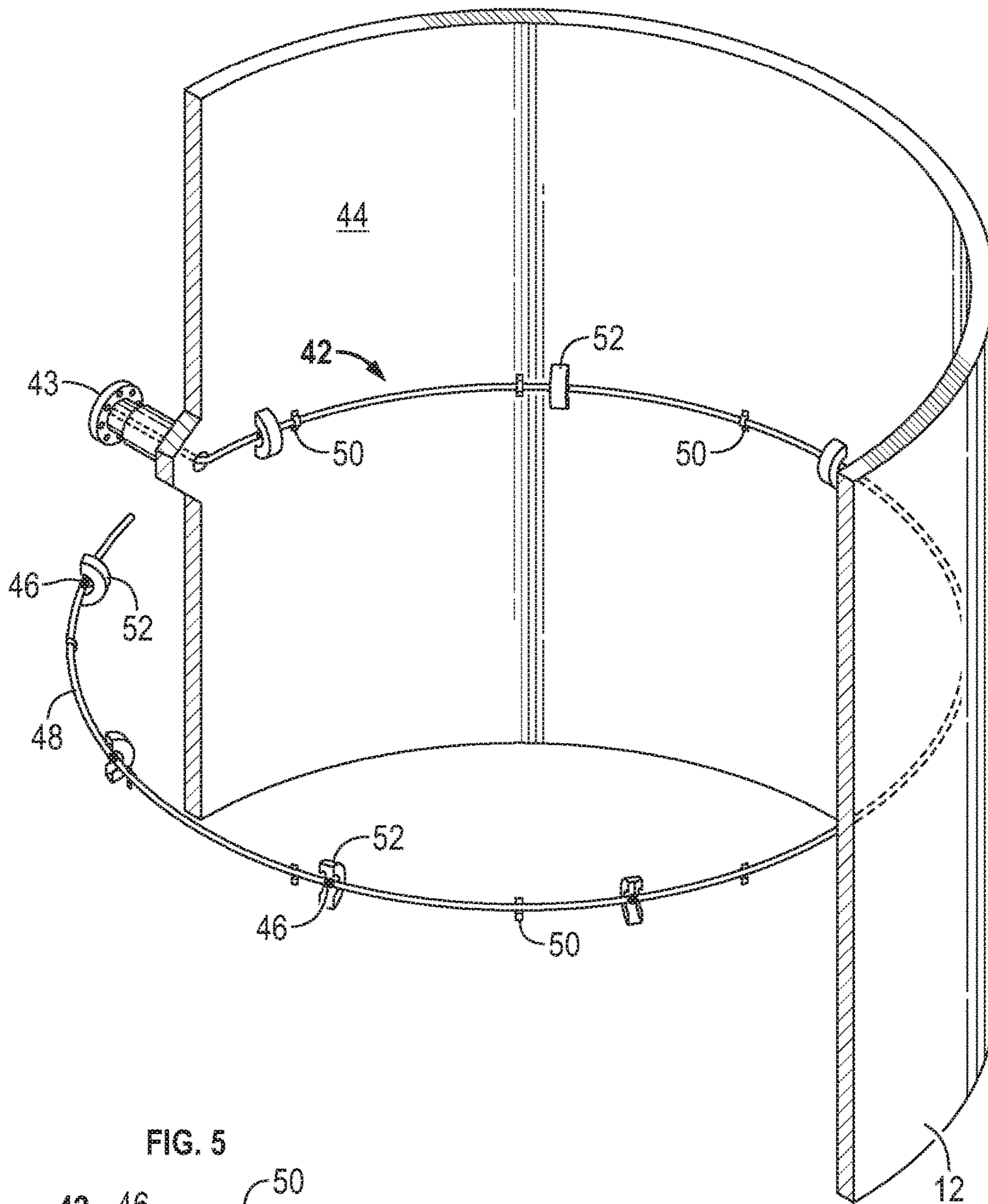


FIG. 5

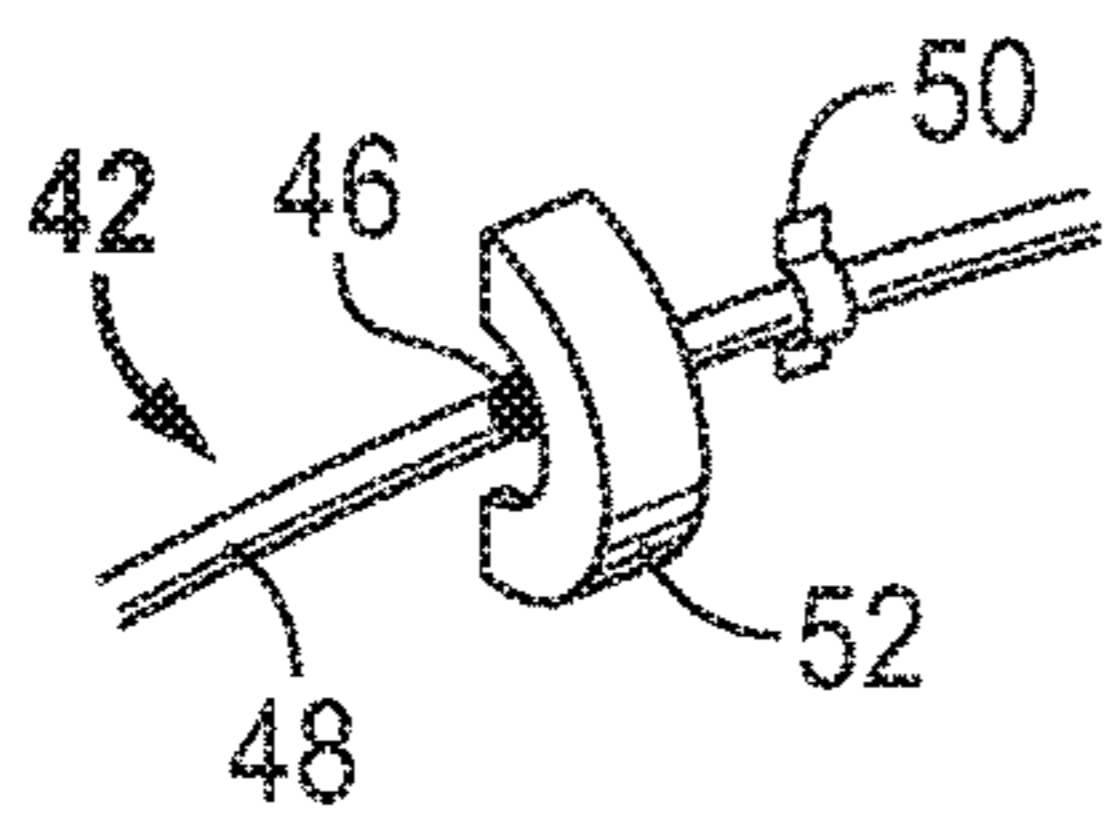


FIG. 6

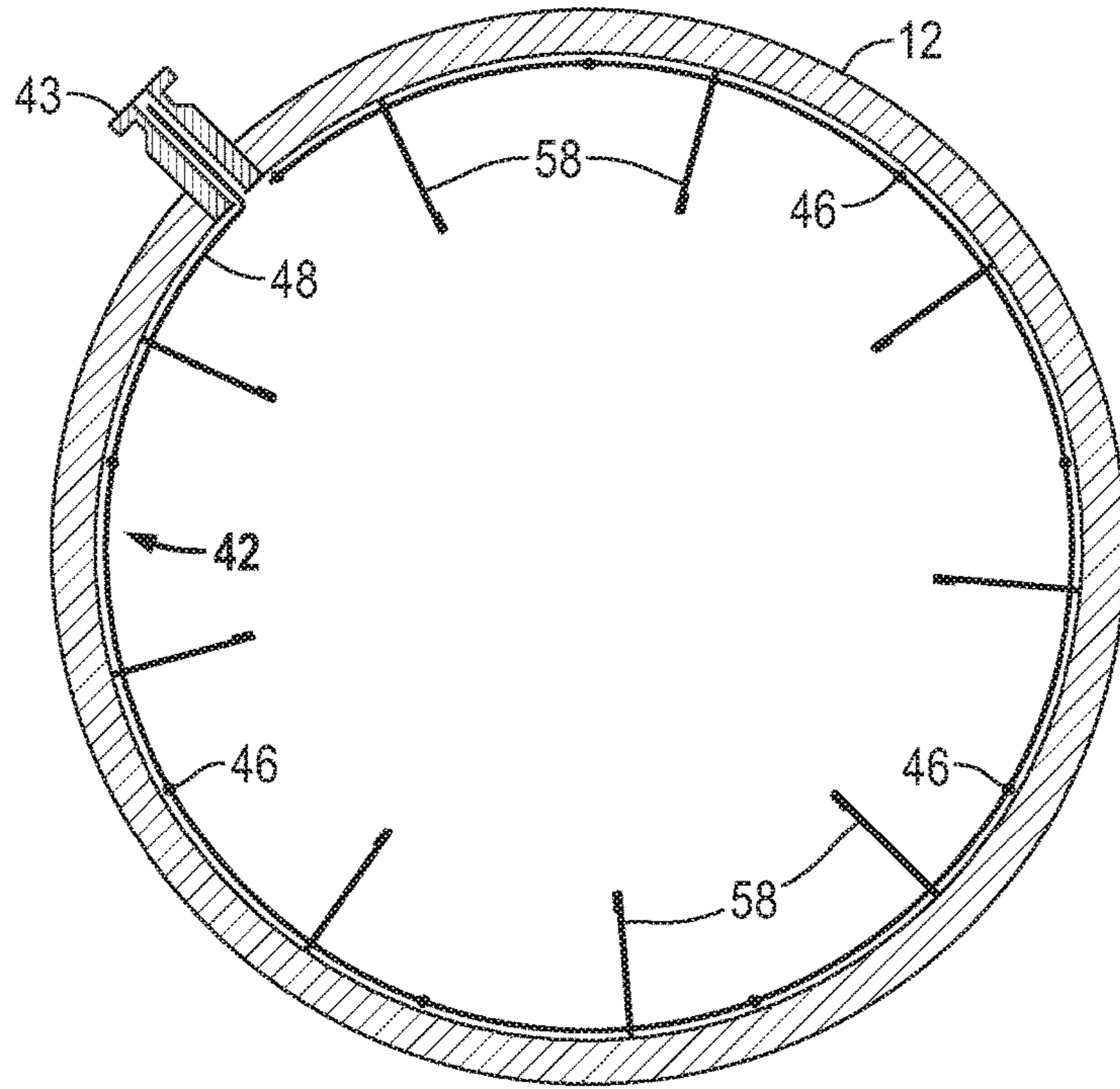


FIG. 7

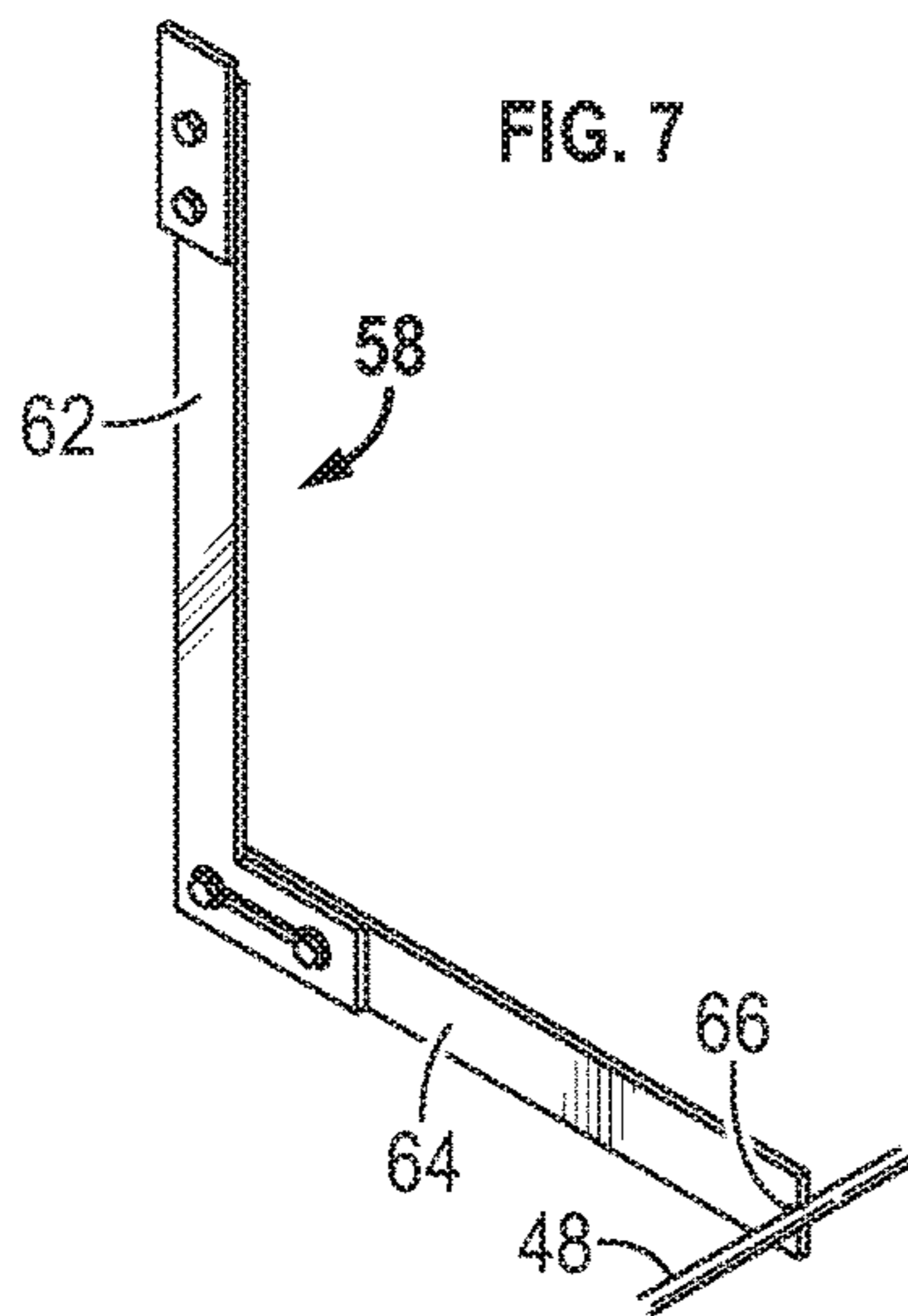


FIG. 8

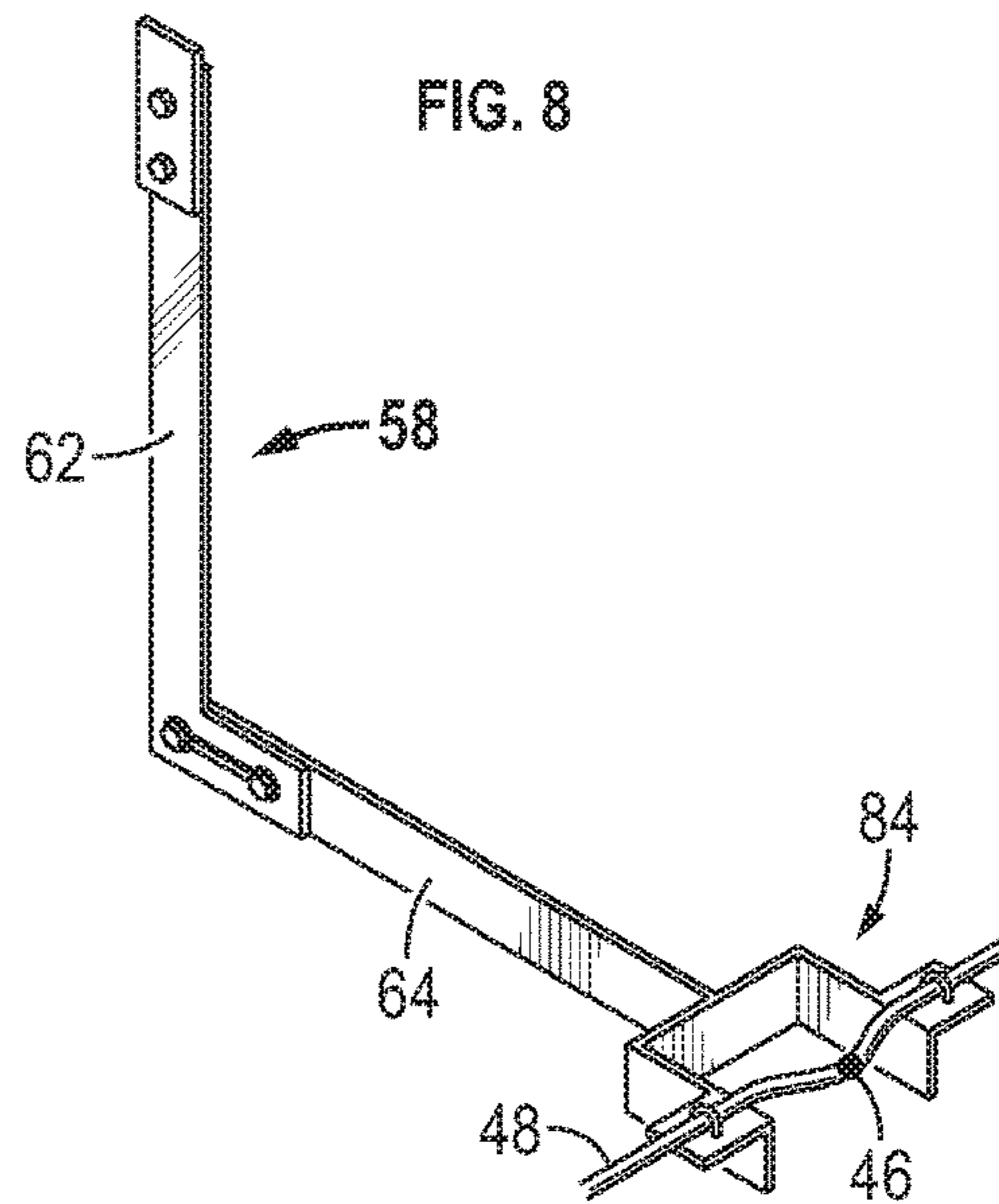
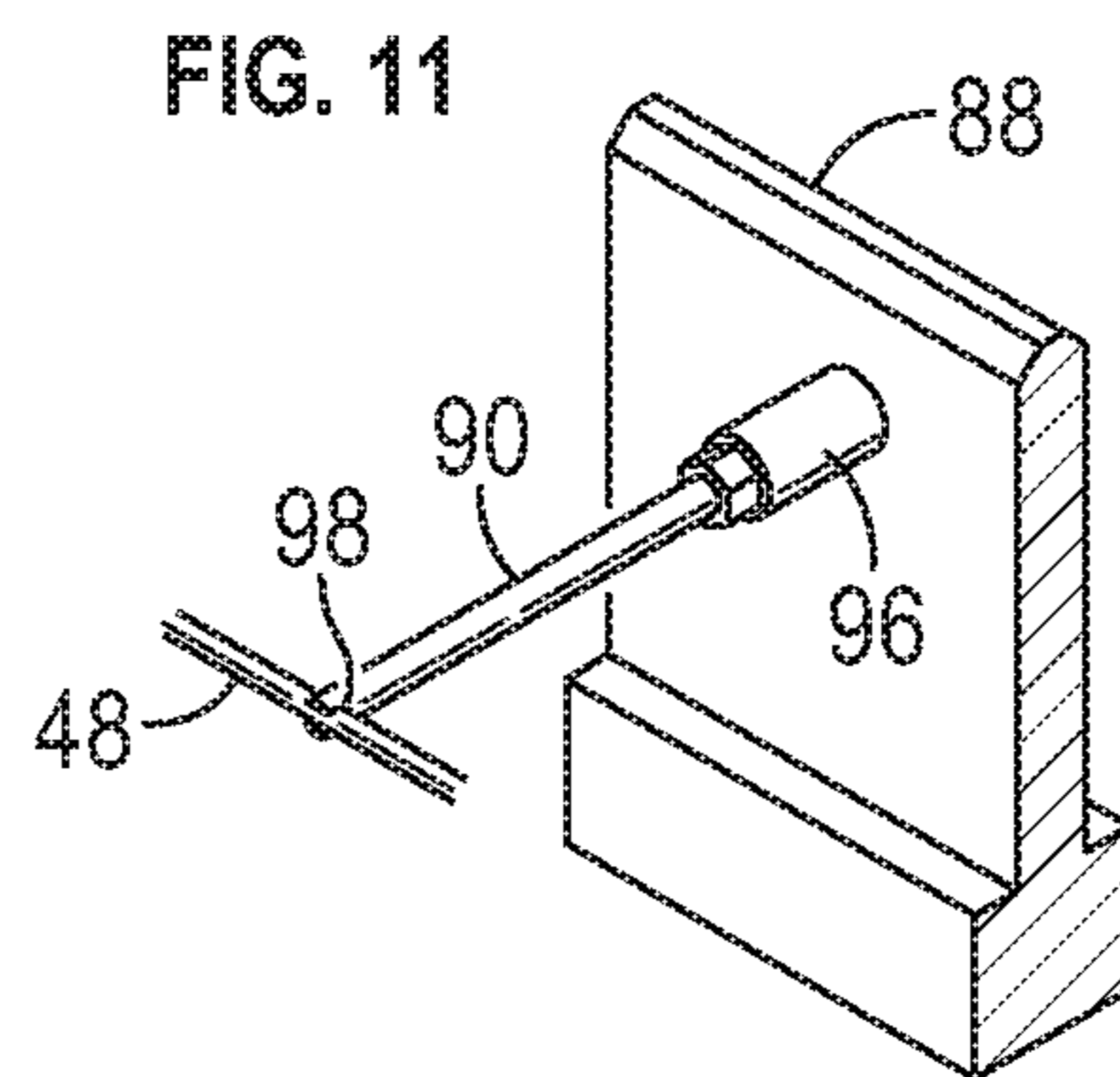
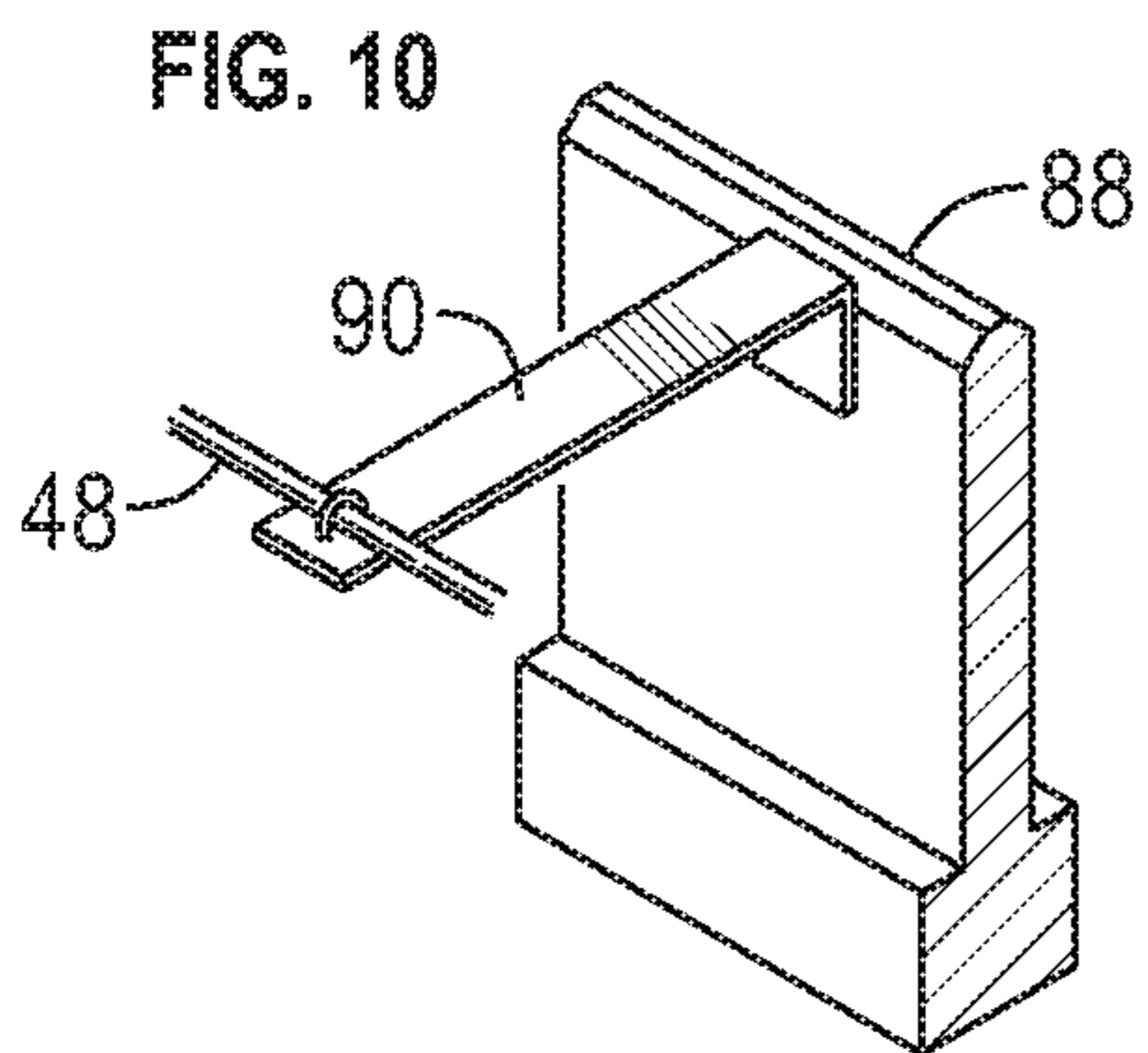
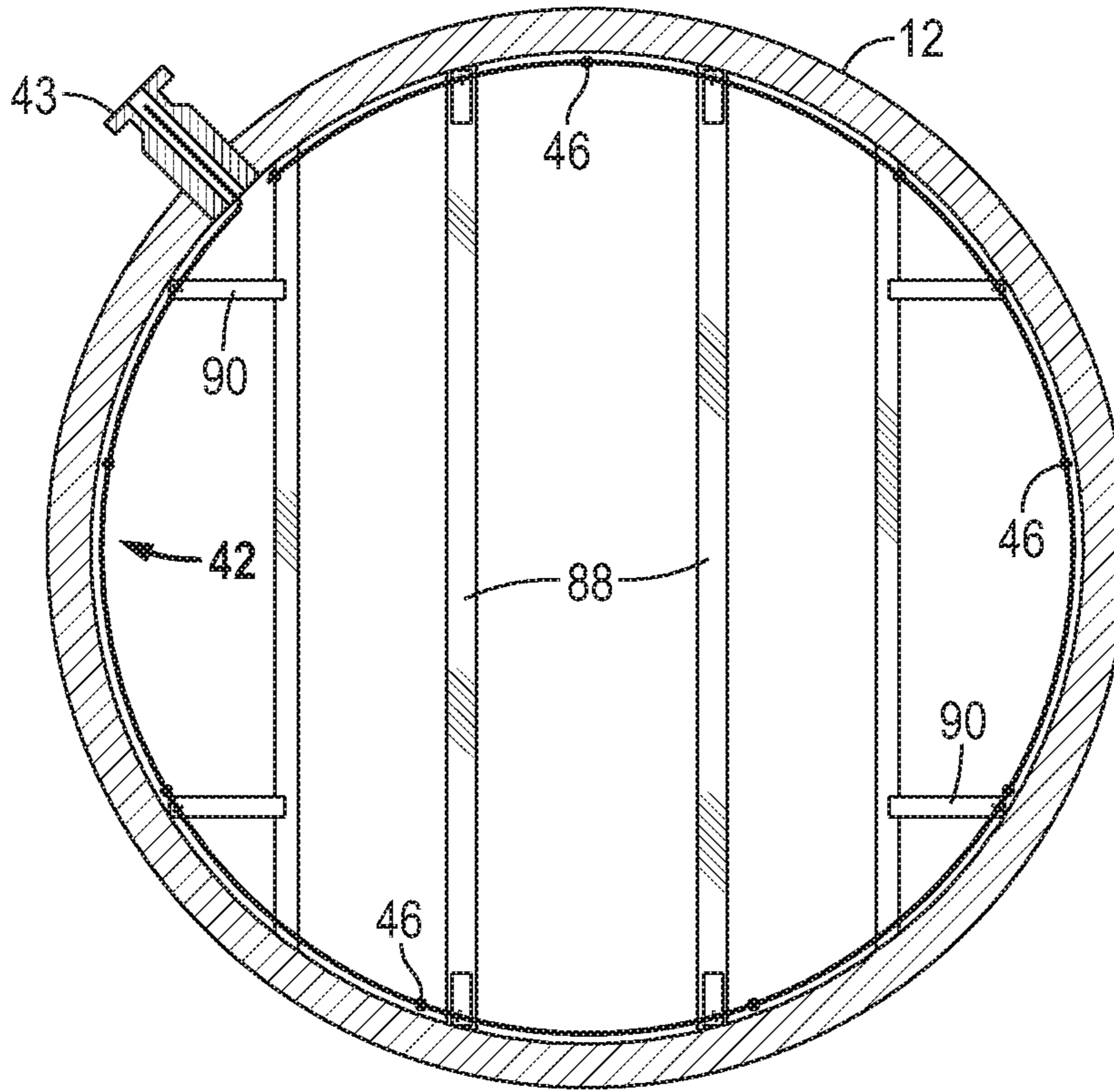
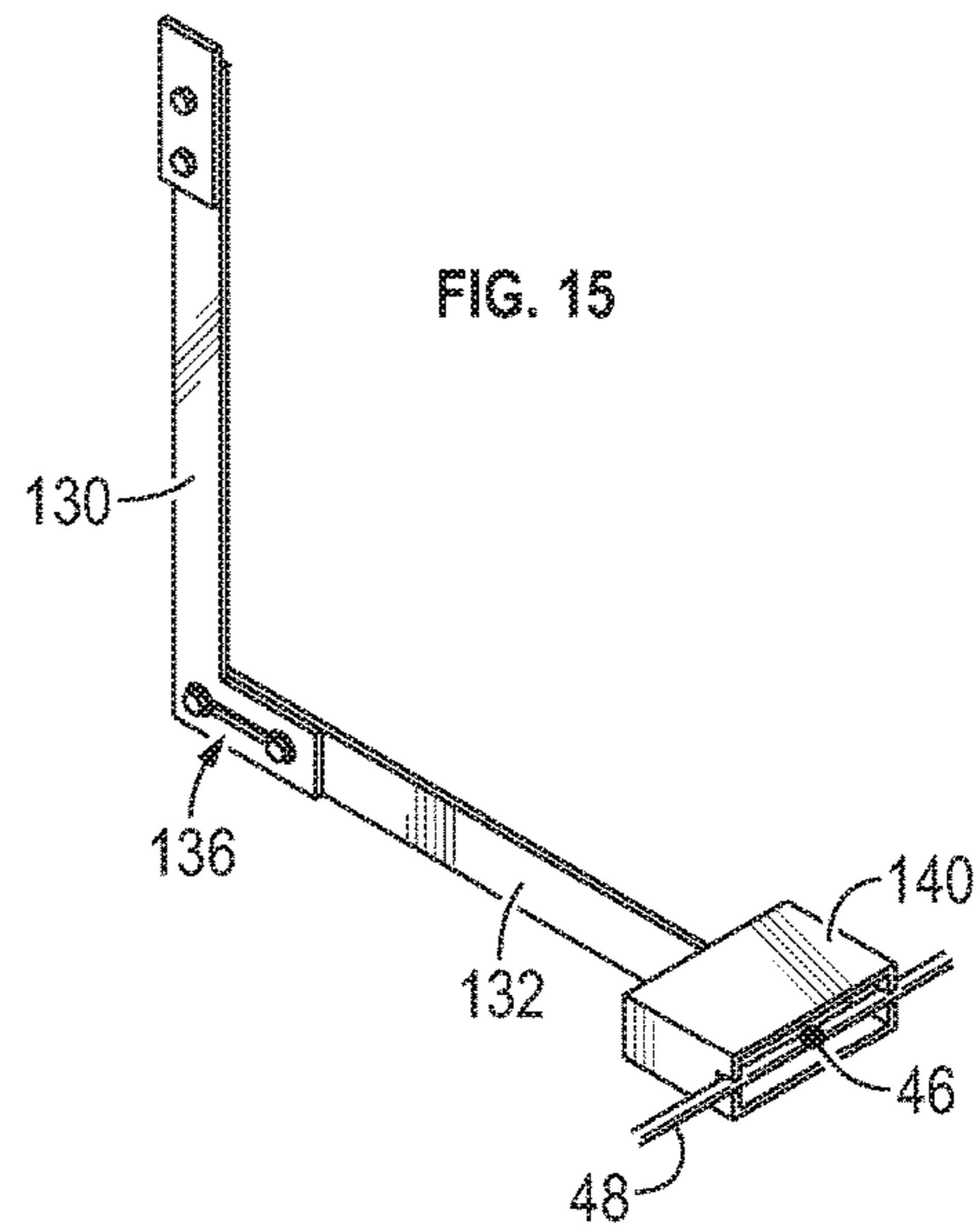
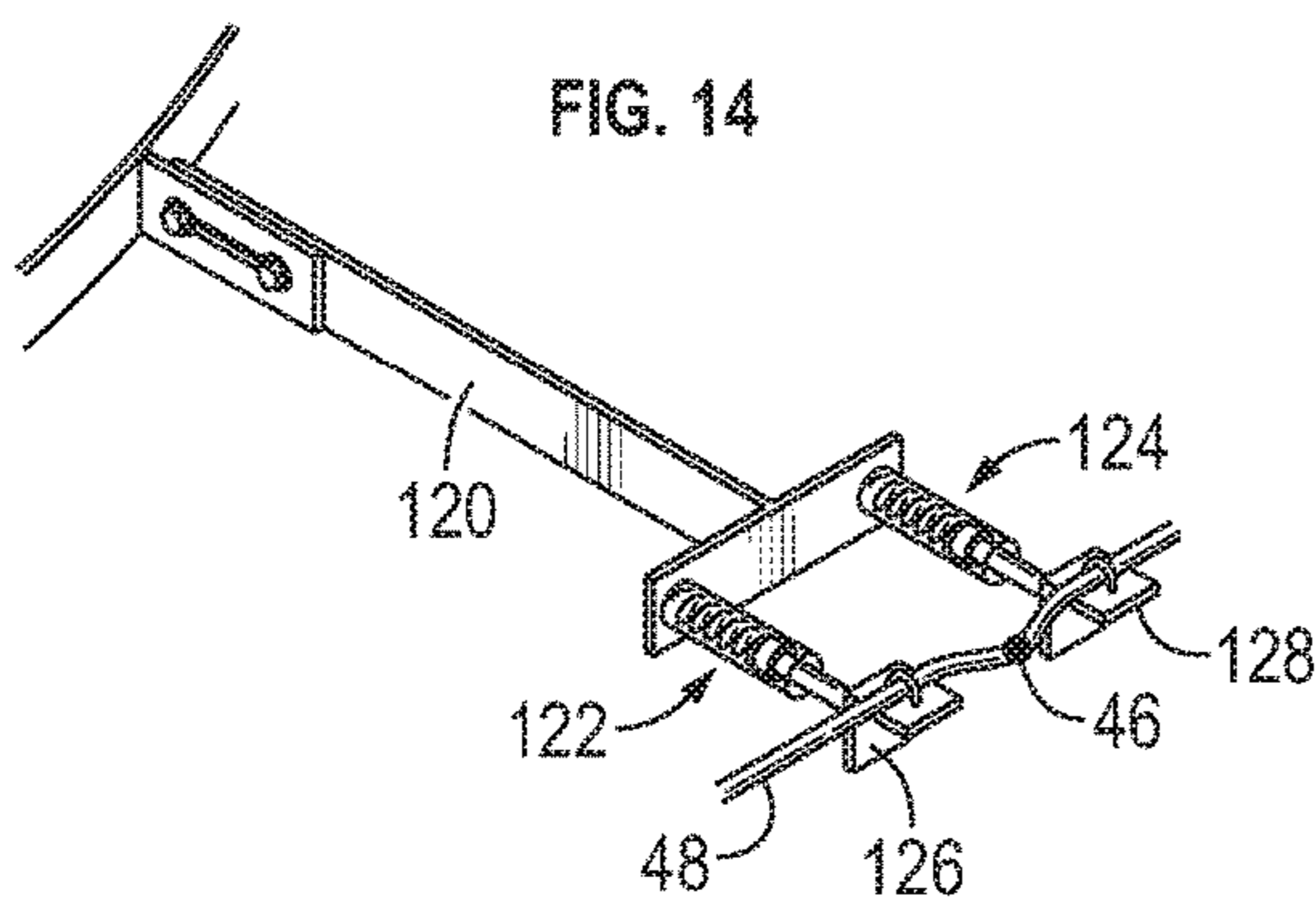
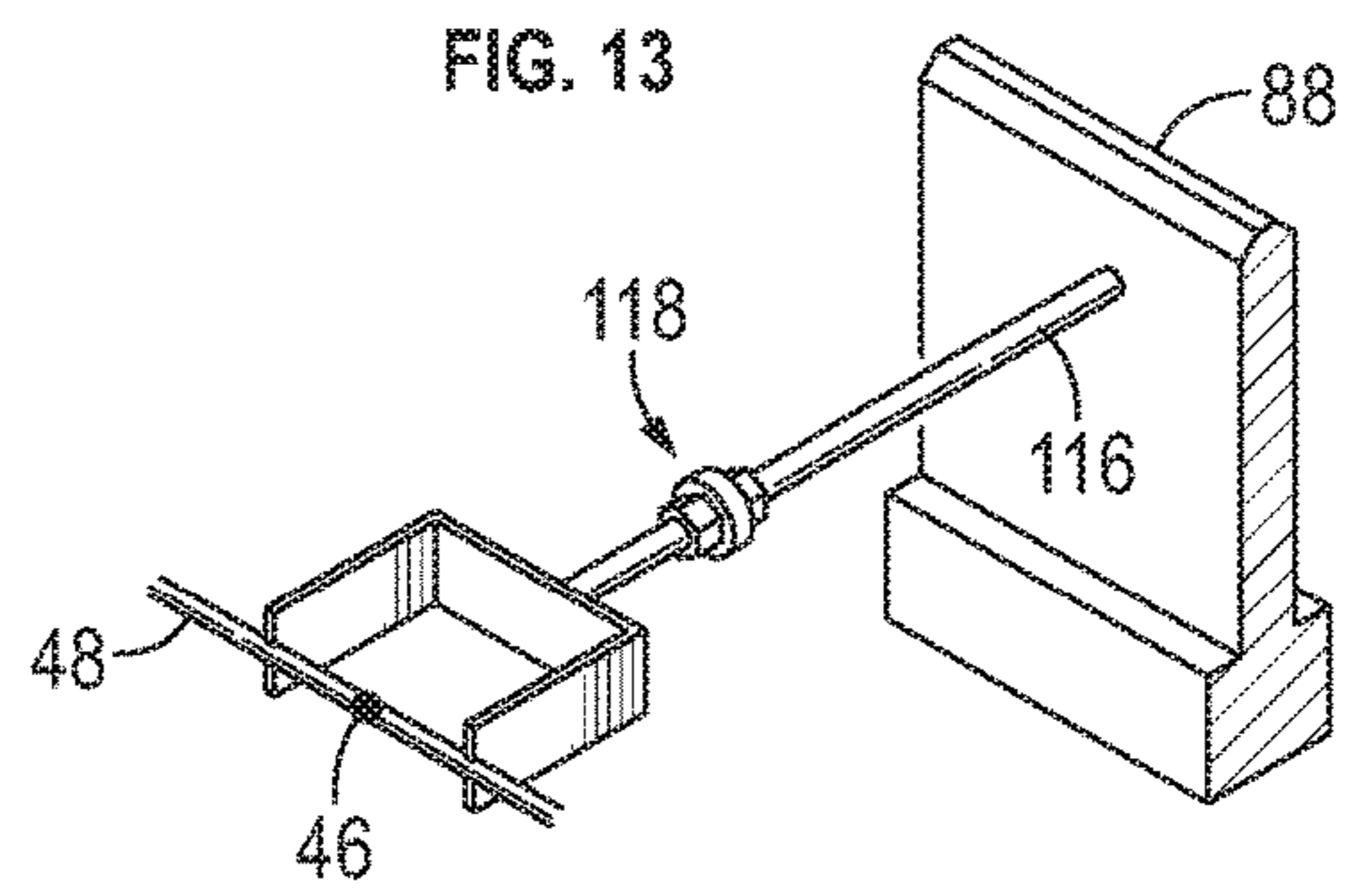
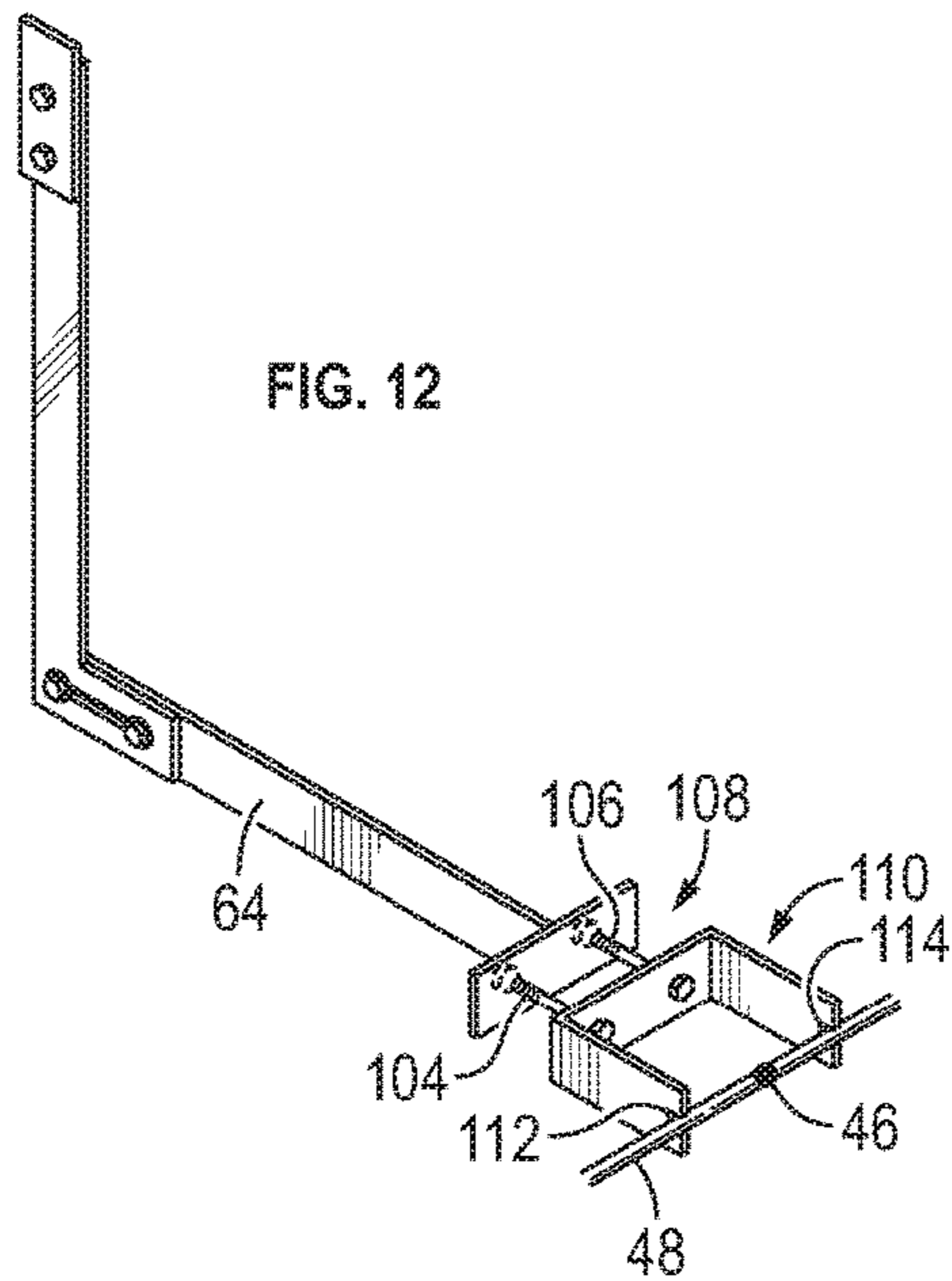


FIG. 9





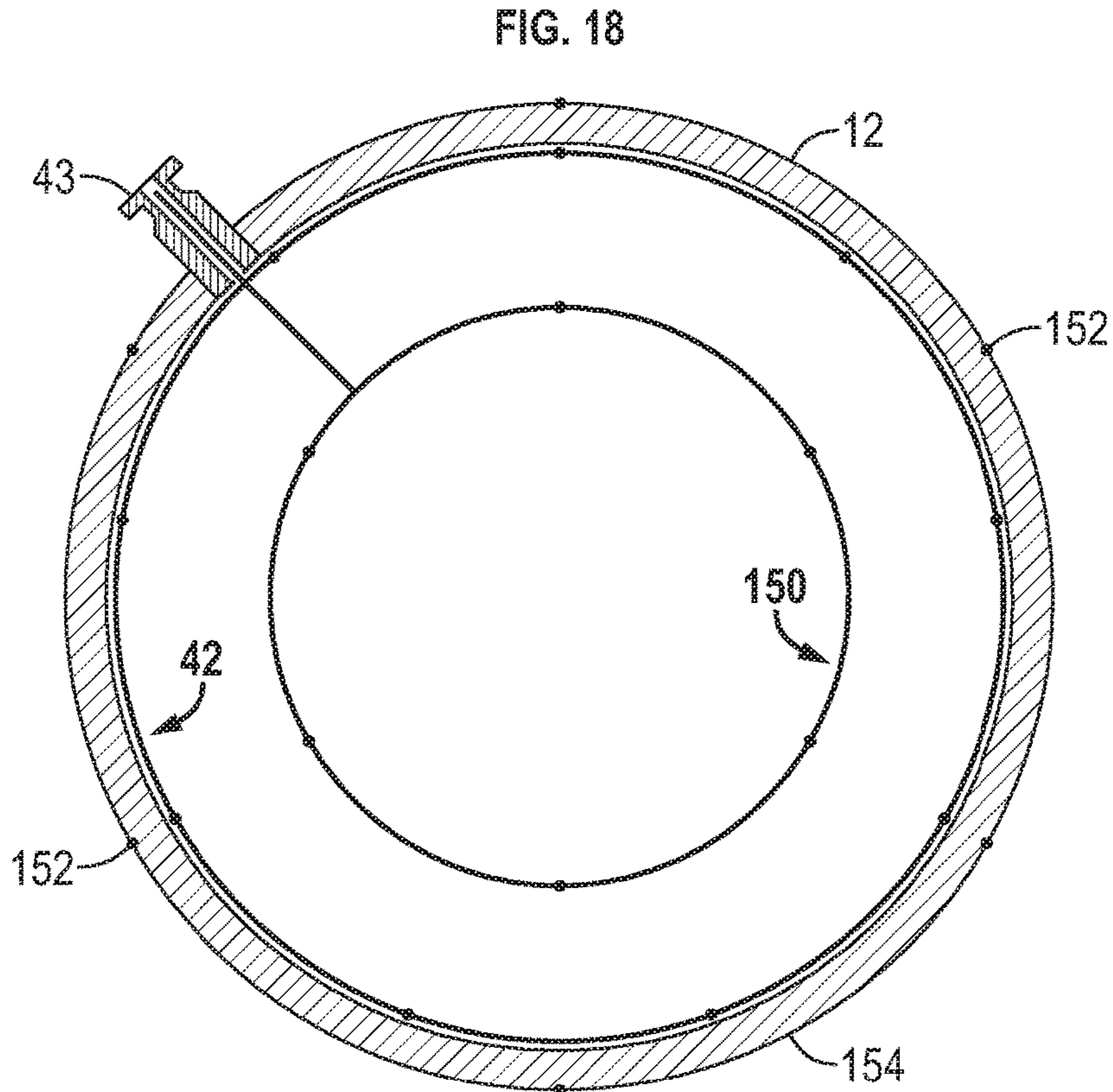
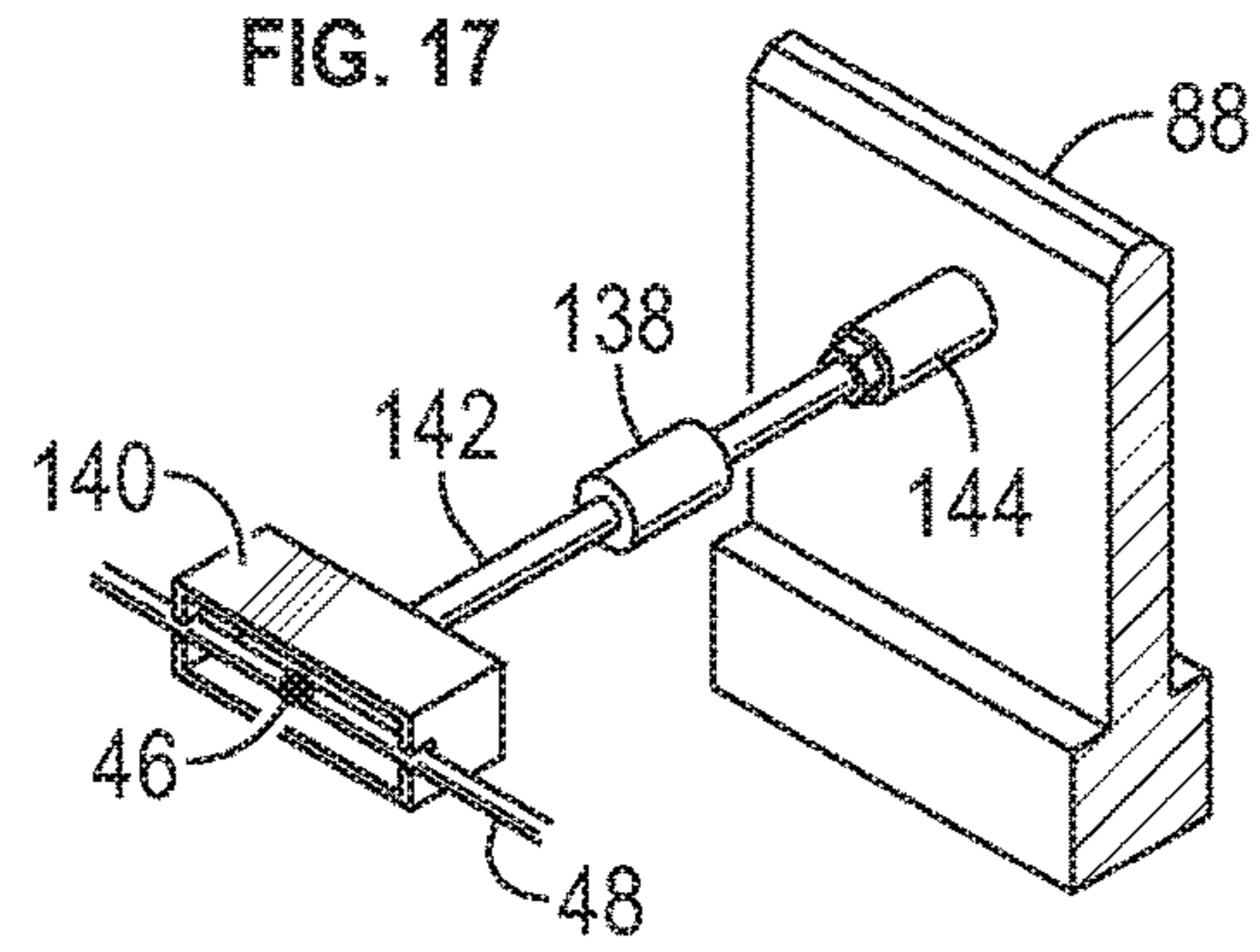
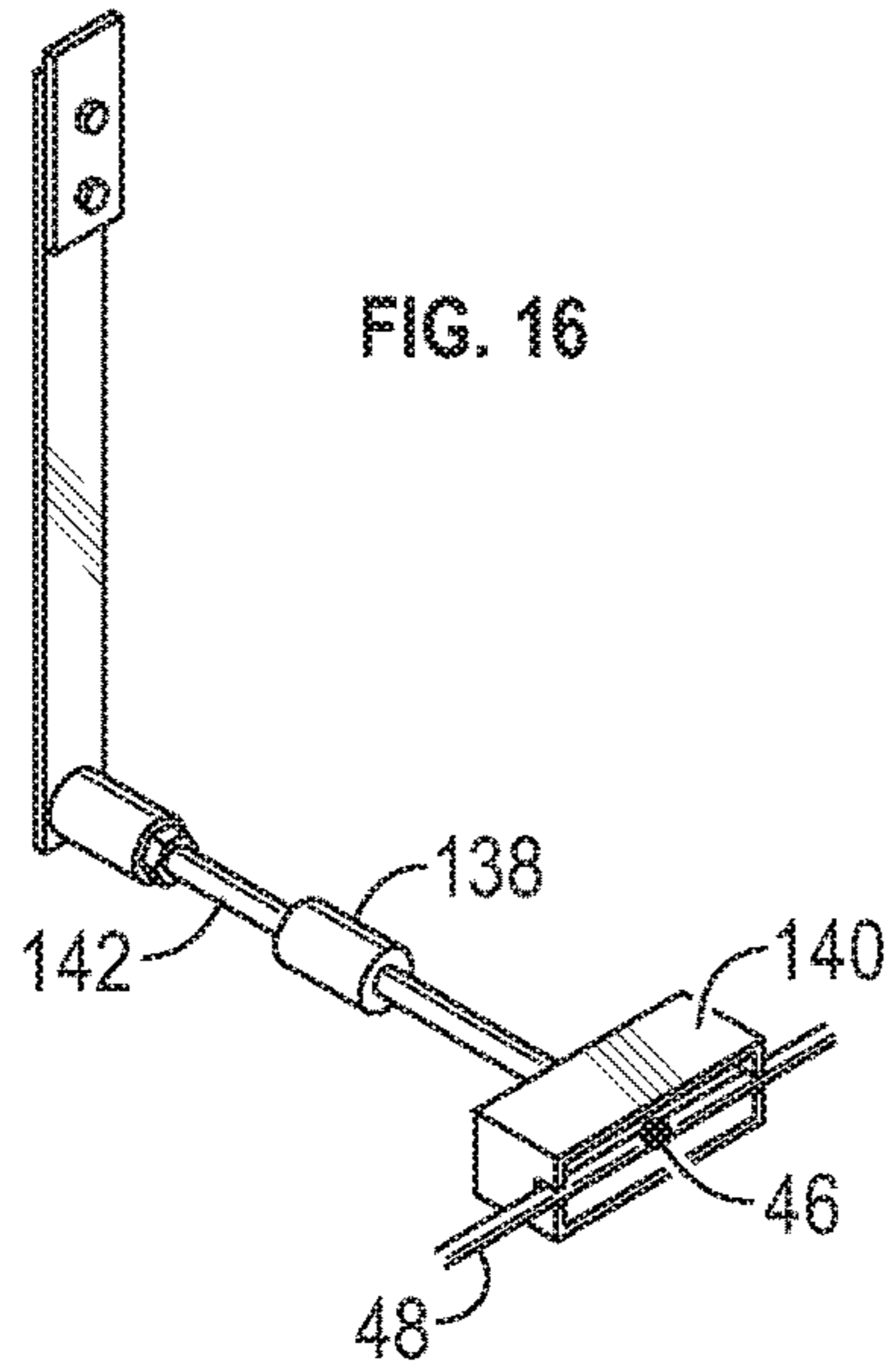


FIG. 19

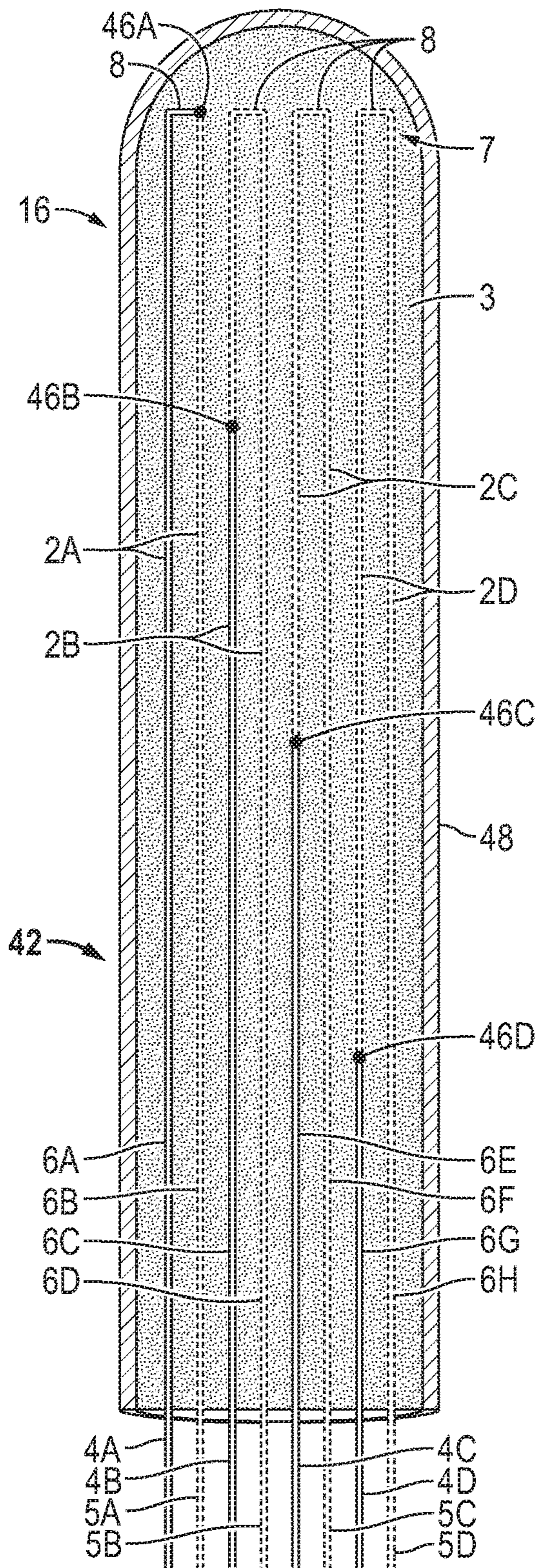
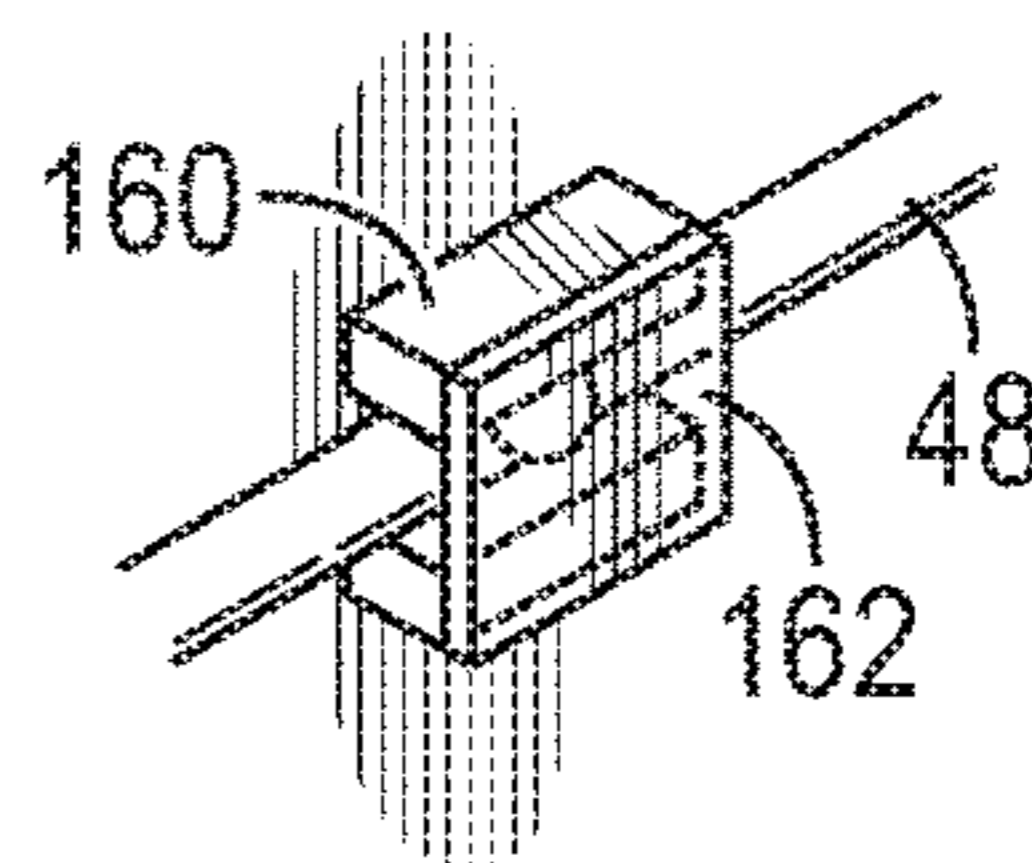


FIG. 20



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**TEMPERATURE SENSING ASSEMBLY FOR
MEASURING TEMPERATURE OF A WALL
OF A HIGH TEMPERATURE VESSEL**

TECHNICAL FIELD

The present invention relates generally to monitoring temperature, and, more particularly, to monitoring temperature of the inner wall of a high temperature vessel, such as a reactor vessel used in the petrochemical and refining industry.

BACKGROUND

The petrochemical and refining industries generally employ various processes where temperature must be measured reliably and accurately. Many of these processes involve treatment of a hydrocarbon material using various catalytic processes that are carried out in a reactor vessel. Typically, such processes involve reacting the hydrocarbon material with hydrogen in a series of catalyst beds, each of which is made up of a material that is suited for the type of hydroprocess performed in the particular bed. These processes are performed at high temperatures, which must be monitored and controlled to ensure that the process is carried out efficiently, but safely without damaging either the vessel or the materials that make up the catalyst beds.

A variety of temperature sensors have been used in conjunction with these processes. For example, temperature sensors can be deployed in a catalyst bed to monitor the temperature of the catalyst for the purpose of maintaining control of the temperature of the process, maximizing the use of the catalyst and/or projecting the remaining useful life of the catalyst. Other temperature sensors can be used to monitor the outer surface (or skin) of a high temperature vessel or tubes or other conduits that are present within a furnace used in a refining process to ensure both that the structure is not overheating and that the process is occurring at a desired temperature. However, neither of these types of arrangements of sensors can provide accurate measurements of the temperature of the inner wall of a high temperature vessel. For instance, while a temperature sensor embedded in the catalyst bed can provide information about the temperature of the process occurring in the bed, it can provide only an approximation of the temperature of the inner wall of the vessel. Similarly, sensors that monitor temperature of the outside wall of the vessel can provide only an approximation of the temperature of the inner wall.

Knowledge of the actual and real-time temperature of the inner wall of a high temperature vessel can lead to more well-informed decisions by an operator of a high temperature vessel. As an example, if the operator is confident that the temperature sensing assembly is providing an indication of the actual temperature of the inner wall (as opposed to an approximation), then the process being performed in the vessel can be implemented at as high of a temperature as possible to obtain maximum yield without concern that the structure of the vessel itself may be overheating. Further, real time measurements of the actual temperature allow the operator to more quickly take remedial actions in the event of a hazardous situation. As an example, during some hydrocarbon processes, petroleum coke accumulations (or coke-ball build ups) may occur within the reactor. Although the coke accumulations can be benign, they also can cause failures if they are near or move towards the reactor wall. Accurate and real-time information about the temperature of the reactor wall (and thus the integrity of the reactor) can

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allow the operator to attempt to lower the temperature of the process by applying a quenching fluid or to take other actions to safeguard the environment and the workers.

BRIEF DESCRIPTION OF THE DRAWINGS

Certain embodiments of the invention will hereafter be described with reference to the accompanying drawings, wherein like reference numerals denote like elements. It should be understood, however, that the accompanying drawings illustrate only the various implementations described herein and are not meant to limit the scope of various technologies described herein. The drawings are as follows:

FIG. 1 is a schematic illustration of a temperature sensing system for sensing temperature in a high temperature vessel, according to an embodiment.

FIG. 2 is a partial cross section of the wall of a high temperature vessel depicting a temperature sensing assembly arranged to monitor temperature along a radial profile of the inner wall, according to an embodiment.

FIG. 3 is a partial cross section of the wall of a high temperature vessel depicting a temperature sensing assembly arranged to monitor temperature along a vertical profile of the inner wall, according to an embodiment.

FIG. 4 is a high temperature vessel depicting a temperature sensing assembly arranged to monitor temperature along a radial profile of the inner wall where the sensing points are shielded with heat shields, according to an embodiment.

FIG. 5 is a detail illustration of a heat shield employed in the arrangement of FIG. 4, according to an embodiment.

FIG. 6 is a cross section of a vessel that includes a temperature sensing assembly arranged to monitor temperature along a radial profile of the inner wall, depicting support structures for supporting the temperature sensing assembly, according to an embodiment.

FIG. 7 is an exemplary support structure for supporting a temperature sensing assembly that can be implemented in the arrangement of FIG. 6, according to an embodiment.

FIG. 8 is another exemplary support structure for supporting a temperature sensing assembly that can be implemented in the arrangement of FIG. 6, according to an embodiment.

FIG. 9 is a cross section of a vessel that includes a temperature sensing assembly arranged to monitor temperature along a radial profile of the inner wall, depicting beams and support structures for supporting the temperature sensing assembly, according to an embodiment.

FIG. 10 is an exemplary support structure for supporting a temperature sensing assembly that can be implemented in the arrangement of FIG. 9, according to an embodiment.

FIG. 11 is another exemplary support structure for supporting a temperature sensing assembly that can be implemented in the arrangement of FIG. 9, according to an embodiment.

FIG. 12 is another exemplary support structure for supporting a temperature sensing assembly that can be implemented in the arrangement of FIG. 6, according to an embodiment.

FIG. 13 is another exemplary support structure for supporting a temperature sensing assembly that can be implemented in the arrangement of FIG. 9, according to an embodiment.

FIG. 14 is another exemplary support structure for supporting a temperature sensing assembly, according to an embodiment.

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FIG. 15 is another exemplary support structure and heat shield for supporting a temperature sensing assembly that can be implemented in the arrangement of FIG. 6, according to an embodiment.

FIG. 16 is another exemplary support structure and heat shield for supporting a temperature sensing assembly that can be implemented in the arrangement of FIG. 6, according to an embodiment.

FIG. 17 is another exemplary support structure and heat shield for supporting a temperature sensing device that can be implemented in the arrangement of FIG. 9, according to an embodiment.

FIG. 18 is a cross section of a vessel that includes a temperature sensing device arranged to monitor temperature along a radial profile of the inner wall, a temperature sensing device arranged to monitor temperature within an interior space of the vessel, and temperature sensing device to monitor temperature on the outer surface of the vessel, according to an embodiment.

FIG. 19 is a cross sectional view of a temperature sensing device that can be used to monitor temperature along the inner wall or within the interior space of a high temperature vessel, according to an embodiment.

FIG. 20 is another exemplary support structure for supporting a temperature sensing assembly, according to an embodiment.

DETAILED DESCRIPTION

Embodiments of the invention provide a temperature sensing assembly for sensing the temperature at multiple locations along or near a profile of the inside wall of a high temperature vessel. The temperature sensing assembly includes multiple sensing points. In some embodiments, the sensing points all are disposed within a single grounded or ungrounded sheath. Alternatively, the temperature sensing assembly can include multiple single point thermocouples arranged to sense temperature at corresponding multiple locations along the inside wall of the vessel. In any embodiment, the temperature sensing assembly is supported at multiple locations along the inside wall of the vessel in a manner that minimizes the distance between the wall and the sensing points. Supports that minimize the distance and stabilize the assembly can include clips, hangers, bosses, and tack welds, as examples. These supports can be used alone or in combination with adjustable or resilient members that position or exert a force that biases the assembly towards or against the wall. In embodiments in which another material, such as a catalyst, is present within the vessel, heat shields may be used to isolate the sensing points from the material or any other thermal sources other than the inner wall of the vessel. In this manner, the temperature sensed by the sensing points more closely reflects the temperature of the inner wall of the vessel.

In embodiments in which multiple sensing points are contained within a single sheath, the sheath of temperature sensing assembly can be twisted (either during manufacture or at the time of installation) in order to position the sensing points so that they are aligned with, and thus adjacent to, the profile of the inner wall of the vessel. Because the temperature data obtained from such a temperature sensing assembly provides an accurate and real-time indication of the actual temperature at multiple points along the inner wall, the operator can allow the process occurring within the vessel to occur at a higher temperature for a higher yield. Likewise, the temperature data can improve the operator's ability to make well-informed decisions regarding a needed or appropriate

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response to a potential over-temperature condition that is occurring near the inner wall of the high temperature vessel.

Referring generally now to FIG. 1, a schematic representation is provided of a system 10 in which exemplary embodiments can be implemented. It should be understood, however, that system 10 is an exemplary application for embodiments of the invention, and that other applications also are envisioned and within the scope of the invention. In the application of FIG. 1, system 10 includes a reactor vessel 12 containing a plurality of vertically spaced hydroprocessing catalyst beds 14 and 16. Although two catalyst beds are shown, it should be understood that the vessel 12 may contain less or more than two catalyst beds, as may be appropriate for the particular hydrocarbon material and the particular hydroprocess(es) or hydrotreatment(s) performed. In the embodiment shown, a feed stream of a hydrocarbon component 20 to be processed is introduced into the top of the vessel 12 so that the feed 20 can thereafter flow downwardly through the series of vertically spaced catalyst beds 14, 16 and exit the vessel 12 as product 22. A quench component or medium 24, such as hydrogen gas or liquid, also is introduced into the vessel 12, such as at the top of the vessel 12 along with the hydrocarbon component 20. The quench component 24 also may be introduced through delivery ports 30 of a quench pipe 32 at a quench zone 26, where a mixing device (not shown) mixes the quench component 24 with the hydrocarbon stream flowing into the zone 26 from the overlying catalyst bed. The quench component 24, which is at a lower temperature than the hydrocarbon stream, generally is used to adjust the temperature of the mixture in the quench zone 26 with the goal of ensuring that the process in the catalyst bed 16 occurs at a temperature that is suited for attaining a maximum yield while not damaging the catalyst material. If hydrogen gas or liquid is used as the quench component 24, quenching also serves to replenish any hydrogen lost by the hydrocarbon stream due to exothermic reactions in the quench zone 26.

In general, the quench zone 26 is defined by a support screen 34, which supports the overlying catalyst bed, and a distribution tray 36, which redistributes the feed mixture across the top of the underlying catalyst bed through delivery ports 38. One or more temperature sensing devices 40 (e.g., single or multipoint thermocouples) are disposed at various locations in the catalyst beds 14, 16 to observe temperature in the vessel 12 and to provide electrical signals representative of the observed temperature to measurement instrumentation 18 that is exterior of the vessel 12. For instance, the temperature sensing devices 40 can be multipoint thermocouple devices, each of which has multiple conductor pairs of dissimilar conductive materials joined at corresponding sensing points. In the embodiment shown, multipoint temperature sensing devices 40 are positioned within each catalyst bed 14, 16 to measure temperature within various regions of the beds 14, 16.

The embodiment of FIG. 1 also includes two temperature sensing devices 42 (e.g., single or multipoint thermocouples) that are arranged to sense the temperature of the inner wall 44 of the vessel 12. Although only two temperature sensing devices 42 are shown, it should be understood that one or more devices 42 can be deployed within a vessel 12 to provide a profile of the inner wall 44 temperature. As examples, the vessel 12 can include multiple multipoint devices 42, each of which provides a vertical profile of temperature at different levels within the vessel 12, as illustrated in FIG. 1. Alternatively or in addition, the vessel 12 can include one or more multipoint devices 42, each of which is arranged to provide a radial (or horizontal) tem-

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perature profile of the inner wall **44** of the vessel **12** at one or more levels within the vessel **12**. Yet further, vessel **12** can include multiple single point thermocouple devices **42** arranged to provide a vertical and/or radial temperature profile of the inner wall of the vessel **12**. Still further, a combination of single point and multipoint thermocouple devices **42** can be used to sense temperature at any desired locations along the inner wall of the vessel **12**.

Turning now to FIG. **2**, a cut away view of the vessel **12** is illustrated that shows an exemplary temperature sensing device **42** arranged to provide a radial temperature profile of the inner wall **44** of the vessel **12**. In FIG. **2**, the temperature sensing device **42** includes a plurality of temperature sensing points **46** disposed within a grounded or ungrounded protective sheath **48**. FIG. **2** further illustrates that the device **42** is fed into the interior of the vessel **12** through a nozzle **43** and is supported on the inner wall **44** of the vessel **12** by a plurality of attachment devices **50**. In the embodiment shown, the attachment devices **50** are generally u-shaped clips that are fastened to the inner wall **44**, such as by tack welds, so that the sensing points **46** are maintained adjacent or in close proximity to the wall **44**.

In other embodiments, such as shown in FIG. **20**, attachment devices **50** may be configured as mounting pads, such as mounting pad **160**, that can be attached (e.g., welded) to the inner wall **44** of the vessel **12**. The sheath **48** can then be mounted on the mounting pad **160** and secured in place with a cover **162**. The cover **162** can be attached to the pad **160**, such as by welding or by attachment devices (e.g., screws). Alternatively, the cover **162** and pad **160** can be configured so that the cover **162** slides over the pad **160** to maintain the sheath **48** in position.

FIG. **3** shows an alternative arrangement, where the temperature sensing device **42** is arranged to provide a vertical profile of the temperature of the inner wall **44** of the vessel **12**. Again, the device **42** is fed into the interior of the vessel **12** through the nozzle **43** and is supported on the inner wall **44** of the vessel **12** by a plurality of attachment devices **50**.

FIG. **4** illustrates a further arrangement where each of the sensing points **46** is shielded from the heat generated by the process occurring within the high temperature vessel by a heat shield **52**. A close-up view of an exemplary heat shield **52** is illustrated in FIG. **5**. The shield **52** is generally u-shaped to fit around the sheath **48** of the device **42** and can be attached to the surface of the inner wall **44** with attachment devices (e.g., screws) or tack welds. The shield **52** can be a solid piece or may have an open interior space (e.g., see heat shields **140** shown in FIGS. **16** and **17**). In some embodiments, the interior space can be filled with an insulative material (e.g., KAOWOOL or INSULFRAX) to further insulate the sensing point **46** from the heat of the process occurring in the vessel **12**. In some embodiments, the interior space **54** is filled with insulative material before assembly in the vessel **12**. In other embodiments, the heat shield **52** can be fixed in position over the sensing point **46** in the vessel **12** and the insulative material can then be injected into the interior space **54**, such as via a slot or opening through the surface of the heat shield **52**, **140** or via an opening or gap at an edge of the heat shield **52**, **140** that provides access to the interior space. In this manner, the insulative material can completely cover the sensing point **46** with no gaps that would expose the sensing point **46** to heat from thermal sources other than the inner wall **44** of the vessel **12**.

The temperature sensing device **42** can be supported on the inner wall **44** of the vessel **12** in a variety of manners,

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such as with attachment devices **50**. In some embodiments, attachment devices **50** can be adjustable or resilient to position or bias the device **42** against or in close proximity to the wall **44** to ensure that the separation between the sensing points **46** and the wall **44** is minimized.

For example, FIG. **6** shows a cross-sectional view of the vessel **12** in which the temperature sensing device **42** is disposed radially about the inner wall **44**. A plurality of adjustable supports **58** are arranged to push the sheath **48** against or towards the wall **44**. The supports **58** can be configured as hangers that hang from supporting beams or brackets within the vessel **12**. Exemplary adjustable supports **58** are shown in FIGS. **7** and **8**. In FIG. **7**, the L-shaped support **58** includes a vertical arm **62** and a horizontal arm **64** that are adjustable in the vertical and horizontal directions, respectively. A distal end of the horizontal arm **64** includes a notch **66** shaped to fit about the sheath **48**. When assembled and adjusted, the arm **64** pushes against the sheath **48** to maintain the sheath **48** in contact with or in close proximity to the surface of the wall **44**.

FIG. **8** illustrates an alternative arrangement where the adjustable support structure **58** is configured to bias the sheath **48** against the inner wall **44** at locations that correspond to the sensing points **46**. In this embodiment, a distal end of the horizontal arm **64** of the support structure **58** includes a fork-shaped bracket **84** that supports the sheath **48** on either side of a sensing point **46**. The portion of the sheath **48** between the arms of the fork-shaped bracket **84** can be bent to bring it into contact with the wall **44** when installed in the vessel **12**. The arrangement shown in FIG. **8** can assist with further ensuring that the sensing points **46** are positioned in close proximity to the inner wall **44**.

In yet other embodiments, and as shown in FIG. **9**, the vessel **12** may include beams **88** or other structures to which supports **90** for the temperature sensing device **42** can be attached. FIGS. **10** and **11** illustrate exemplary supports **90** that can be attached to a beam **88**. In FIG. **10**, the support **90** provides a platform to which the sheath **48** is attached. FIG. **11** illustrates an alternative arrangement where a support arm **90** is screwed into a coupling **96** attached to the beam **88**. The length of the arm **90** can be adjusted depending on the extent to which the arm **90** is threaded into the coupling **96**. The distal end of the arm **90** includes a notch **98** shaped to hold the sheath **48**. In this manner, the sheath **48** can be pressed towards and/or into contact with the inner wall **44**. Other adjustable arrangements also are envisioned where the length of the support arms can be adjusted so as to provide a biasing force that pushes the sheath **48** towards and/or into contact with the inner wall **44**. Such adjustable arrangements can include the use of slots, bolts, threads, or spring loaded couplings, as examples.

Examples of such arrangements are shown in FIGS. **12-14**. In FIG. **12**, the length of the arm **64** can be adjusted through the use of threaded fasteners **104** and **106** that vary the size of a gap **108** between a fork-shaped bracket **110** and the distal end of the arm **64**. The ends of the bracket **110** include notches **112** and **114** that are arranged to receive the sheath **48**. During installation, the gap **108** can be adjusted so that at least portions of the sheath **48**, such as the portion of the sheath **48** that corresponds to the sensing point **46**, contact or are in close proximity to the inner wall **44** of the vessel **12**. In FIG. **13**, the length of an arm **116** is adjusted through the use of a spring-loaded union **118**. In FIG. **14**, a biasing force provides by an arm **120** is adjusted via the use of spring loaded pistons **122** and **124**. Ends of the pistons **122** and **124** are coupled to support brackets **126** and **128** for holding the sheath **48**.

Any of these support arrangements can be used with individual heat shields that shield each of the sensing points **46** from the heat of the process occurring inside the vessel **12** or from any other thermal source other than the wall **44**. Examples of such arrangements are illustrated in FIGS. **15-17**. In FIG. **15**, arms **130** and **132** of a hanger are connected via a slotted threaded coupling **136**. Heat shield **140** is attached to arm **132** for positioning over a sensing point **46**. The heat shield **140** can be removably attached, such as via a resilient clip (not shown). As shown in FIG. **16**, an arm **142** can include a spring-loaded coupling **138** to bias the sheath **48** and heat shield **140** into close proximity to the inner wall **44** of the vessel **12**. In FIG. **17**, the arm **142** and heat shield **140** assembly is coupled to support beam **88** via a threaded coupler **144**. In the embodiment shown, the arm **142** and heat shield **140** assembly is configured to exert a biasing force via the spring loaded coupler **138** so as to urge the sensing point **46** of the thermocouple device **42** into close proximity to the wall **44** of the vessel **12**.

When a heat shield **140** is employed, the heat shield can be filled with an insulative material (e.g., KAOWOOL™ or INSULFRAX® as examples) to further thermally isolate the sensing point **46** from heat from other sources. The insulative material can be present in the interior space of the heat shield **140** prior to installation in a vessel **12**. In other embodiments, the temperature sensing device **42** and support and heat shield assemblies may first be installed in a vessel **12** and the insulative material can then be injected into the interior space of the heat shield **140**. In some embodiments, the heat shield **140** can be removably attached to the support arm or to the sheath **48**, such as via a resilient clip.

The temperature sensing device **42** can be used in conjunction with other multipoint and/or single point temperature sensing devices that are arranged to monitor temperature at locations other than the inner wall **44** of the vessel **12**. For example, as shown in FIG. **18**, the vessel **12** includes a multipoint sensing device **42** to monitor the temperature at multiple points along the inner wall **44**, a sensing device **150** to monitor temperature of the process occurring with the vessel **12** (such as within a catalyst bed) and one or more single point sensing devices **152** to monitor the temperature on the outer wall **154** of the vessel **12**. In the embodiment shown, the inner wall sensing device **42** and the catalyst bed sensing device **150** are fed through the nozzle **43** into the interspace of the vessel **12** and then positioned and supported in there by appropriate hanger and/or support arrangements, such as any of the arrangements illustrated in the figures described herein.

As discussed, in certain implementations, the thermocouple device **42** can have multiple sensing points **46** disposed at unique locations along the length of the sheath **48**. An example of multiple sensing points **46** contained within the sheath **48** of device **42** is shown schematically in the cross-section view of FIG. **19**. In this implementation, the sheath **48** comprises an open interior into which four conductor pairs **2A**, **2B**, **2C** and **2D**, extend. Although four conductor pairs **2** are shown, fewer or more conductor pairs may be included within the sheath **48**. An insulation material **3**, such as an electrical insulation material, is disposed about the individual conductors of the conductor pairs **2A-D**. The insulation material **3** generally fills the interior about the conductor pairs **2A-D**. Although various electrical insulation materials may be used, an exemplary material comprises magnesium oxide (MgO).

With reference to FIG. **19**, temperature can be determined at a plurality of locations along the length of the sheath **48**

by forming junction points **46A**, **46B**, **46C**, **46D** at selected locations along the sheath **48**. By way of example, the embodiment of FIG. **19** illustrates four conductor pairs **2A-D** each having its own unique junction point **46A-D**, respectively. The junction points **46A-D** are formed at unique longitudinal locations along the sheath **48** to permit the sensing of temperature at those unique locations.

Each conductor pair **2A-D** comprises a first conductor **4** (i.e., **4A**, **4B**, **4C**, or **4D**) illustrated in solid line and a second conductor **5** (i.e., **5A**, **5B**, **5C** or **5D**) illustrated in dashed line in FIG. **19**. The first conductor **4** and the second conductor **5** of each conductor pair **2** are made of dissimilar conductive materials, such as iron/constantan, chromel/alumel, copper/constantan, chromel/constantan, etc. Various combinations of different conductor pair types can be utilized within a single sheath or the conductor pairs may all be of the same type. A variety of materials also may be used to form the sheath **48**, such as stainless steel and Inconel, as may be appropriate for the particular application in which the thermocouple device **42** is employed.

Although a variety of techniques may be used to join the dissimilar conductors **4A-D/5A-D** at desired junction points **46A-D** within the sheath **48**, one technique is to provide conductor pairs **2A-D** by forming a plurality of rods **6A-H** that extend into the sheath **48** to distal end **7**. The rods **6A-H** are preformed of the material of first conductor **4A-D**, second conductor **5A-D**, or a combination of the two conductors. When the rods **6A-H** are placed within the sheath **48**, the junction points **46A-D** are disposed at desired locations for sensing temperature.

Each of the rods **6A-H** has a distal rod end **8**, and the appropriate pairs of rod ends **8** are joined together to form conductor pairs **2A-D**. Although distal rod ends **8** may be joined in a variety of manners, the distal rod ends **8** may be fused, e.g., welded, together at a fusion end **66**. Alternatively, a cross piece or cross rod may be utilized. For example, a cross piece formed of the appropriate conductor material may be welded or otherwise joined to corresponding rod ends. As shown in FIG. **19**, the rods **6A-H** of a conductor pair **2A-D** remain spaced apart from one another along the entire length of the sheath **48** until they are joined at their respective distal ends **8** at the distal end **7** of the sheath **48**.

Although various processes may be used to form the thermocouple device **42**, one exemplary methodology comprises preparing the rods **6** having dissimilar materials by, for example, welding the dissimilar conducting materials together at a predetermined point **46**. The combination rods **6** along with the remaining rods **6** are then passed through the insulation **3** within the open ended sheath **48**. The insulation **3** may initially be placed within the sheath **48** in the form of beads. The sheath **48** is then swaged to compact the insulation **3** and the sheath **48**.

Following swaging, the insulation **3** is removed at the distal end **7** and the appropriate rods **6** are coupled to form conductor pairs **2**. For example, cross pieces **8** may be welded across appropriate rod distal ends. An appropriate insulation material **3**, such as magnesium oxide powder, is placed around the protruding rod ends and a sheath cap can be attached to the remainder of the sheath **48** by, for example, welding.

In other embodiments, the conductor pairs can comprise two wires made of dissimilar materials and the junction points may be formed by welding the wires at a desired location along their length.

Regardless of the manner in which the conductor pairs and junction points are formed, in various implementations,

the sheath **48** can be twisted to align each of the junction points **46** in a manner that aligns the points **46** with the profile of the inner wall **44** of the vessel **12**. This twisting can be done either prior to or during the installation of the temperature sensing device **42** in the interior of the vessel. ⁵ Alignment of the junction points **46** with the wall **44** and the support arrangements that maintain the junction points **46** in position ensure that the set of temperature data obtained from the device **42** is indicative of the actual temperature of the wall **44** of the vessel **12**. Armed with a data set that accurately reflects the actual wall temperature, the operator ¹⁰ of the vessel **12** can then make decisions that allows the process within the vessel to be performed at a higher temperature, thus increasing yield without compromising reliability.

Although the various embodiments above have been described in the context of measuring the temperature of the inner wall of a high temperature vessel used for processing hydrocarbons, it should be understood that embodiments can be implemented in any application where temperature measurements of the inner wall of a vessel or other structure is desired. It should further be understood that such embodiments fall within the scope of the appended claims. ²⁰

While the invention has been disclosed with respect to a limited number of embodiments, those skilled in the art, ²⁵ having the benefit of this disclosure, will appreciate numerous modifications and variations therefrom. It is intended that the appended claims cover such modifications and variations as fall within the true spirit and scope of the invention.

What is claimed is:

1. A method of monitoring temperature of an inner wall of a vessel, comprising: ³⁵
 positioning a thermocouple assembly within an interior of the vessel, wherein the thermocouple assembly comprises a plurality of junction points disposed to measure temperature at a plurality of corresponding unique locations on the inner wall of the vessel, wherein the

thermocouple assembly is positioned within the interior of the vessel so that the plurality of junction points are aligned with a profile of the inner wall of the vessel; supporting the thermocouple assembly within the interior of the vessel so that the junction points are maintained in close proximity to the corresponding unique locations on the inner wall of the vessel; positioning a heat shield over each junction point to shield the junction point from heat from thermal sources other than the inner wall of the vessel; and filling an interior space of the heat shield with a thermally insulative material after the heat shield is positioned over the junction point.

2. The method as recited in claim **1**, wherein the plurality of junction points are disposed within a single elongate sheath, and the method further comprising twisting the elongate sheath to align the plurality of junction points with a profile of the inner wall of the vessel. ¹⁵

3. The method as recited in claim **2**, wherein the profile is a vertical profile. ²⁰

4. The method as recited in claim **2**, wherein the profile is a horizontal profile.

5. The method as recited in claim **1**, further comprising attaching a plurality of support arms to the inner wall of the vessel, the support arms to support the thermocouple assembly and to position the junction points proximate the inner wall of the vessel. ²⁵

6. The method as recited in claim **5**, further comprising adjusting the support arms so that the support arms exert a force that biases the junction points towards the inner wall of the vessel. ³⁰

7. The method as recited in claim **6**, further comprising coupling at least one of the heat shields to a distal end of a support arm, and positioning the heat shield over a junction point to shield the junction point from heat from thermal sources other than the inner wall of the vessel.

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